



NREL Projects with the Corn Ethanol Industry

BIOENERGY 2000

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Presentation Outline

- USDA/NREL project
- Building a Bridge to the Corn Ethanol Industry - Engineering study results
- New ventures with the corn ethanol industry as a result of building the bridge

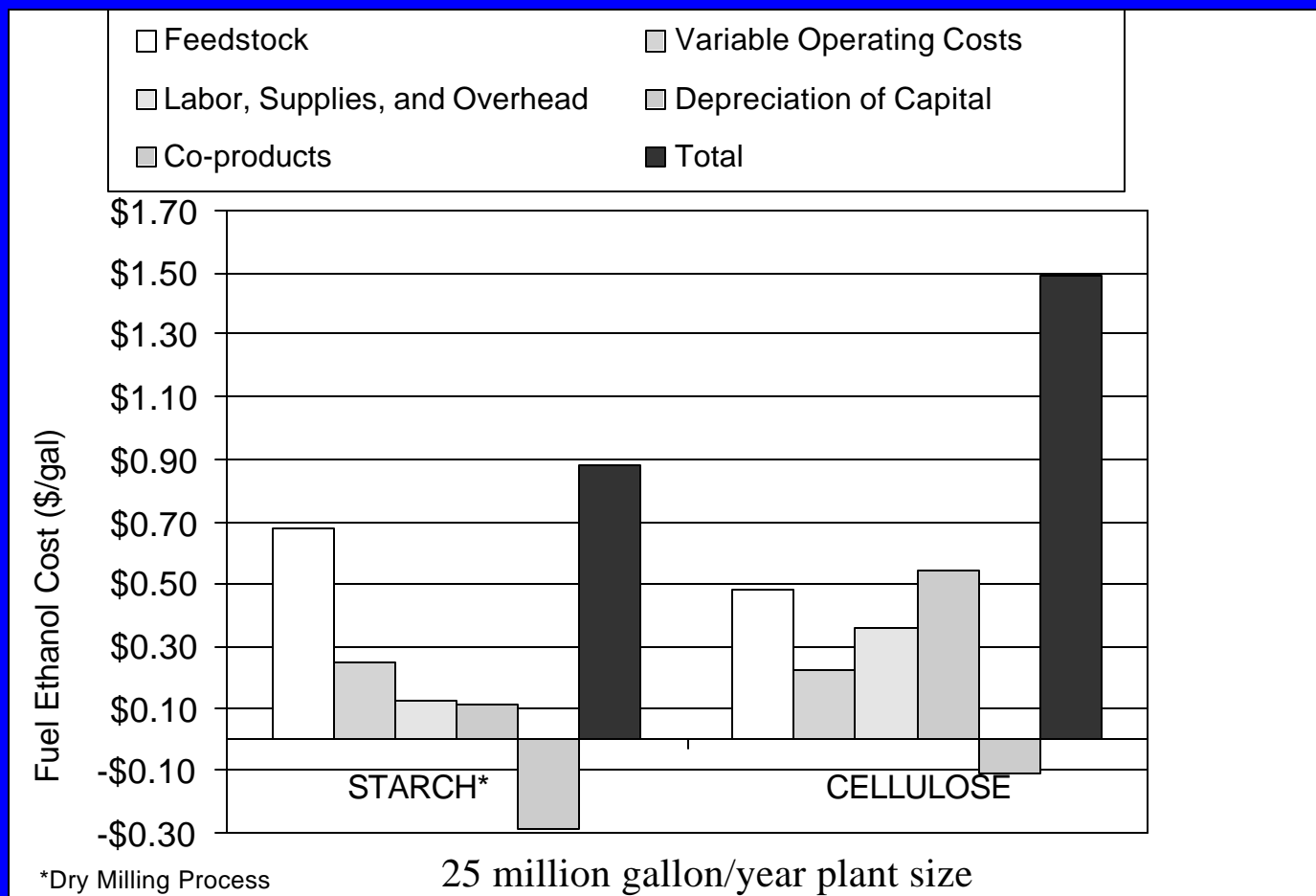


USDA/NREL Project

- A two-phase project to compare ethanol production from corn starch (dry mill) and corn stover (enzymatic process)
- In phase 2 combine starch and stover technologies to explore cost-saving opportunities from integration
- Collaborative opportunity with USDA to combine expertise and share technology

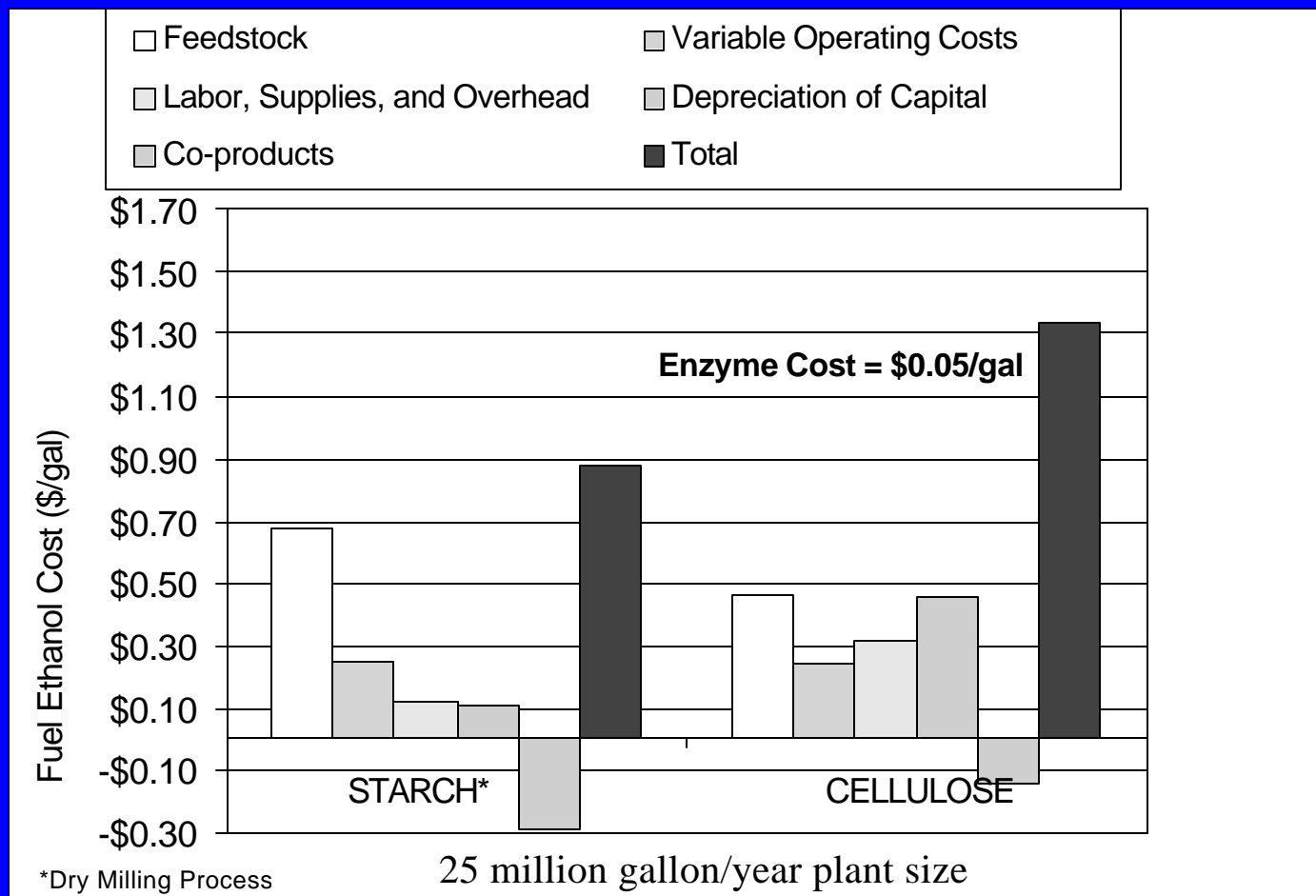


USDA/NREL Project Phase 1 Results





USDA/NREL Project Using Purchased Enzyme





USDA/NREL Project

Phase 2 Plan

- Create a combined corn and stover process design and model
- Explore cost savings from integration
- Determine the most cost sensitive parameters in the integrated process
- Recommend studies to positively affect these areas



Bridge to the Corn Industry – Engineering Study Goals

- Provide industry an opportunity to explore business potential of using other feedstocks
- Take advantage of existing corn ethanol industry infrastructure
- Obtain feedback to guide research for commercialization
- Required enzymatic process design



Bridge Participants

- Completed:
 - Merrick - High Plains Ethanol (York) - PureVision Technologies
 - Vogelbusch - Chief Ethanol - KAPPA
 - Purdue - Williams Energy Services - USDA NCAUR
 - NYSTEC - Robbins Corn - Raytheon
 - Weatherly - High Plains Ethanol (Portales) - SWAN
- Underway:
 - Delta T - Chippewa Valley Ethanol



Bridge Results

- Conversion of corn fiber to ethanol (Purdue-Williams-USDA project) resulted in promising ethanol production costs:
 - \$0.67 to \$1.01/gallon production cost
- Process designs minimized integration due to concerns about DDG sales
- Closer integration, cellulase enzyme cost reduction plus other process improvements can produce profitable scenarios



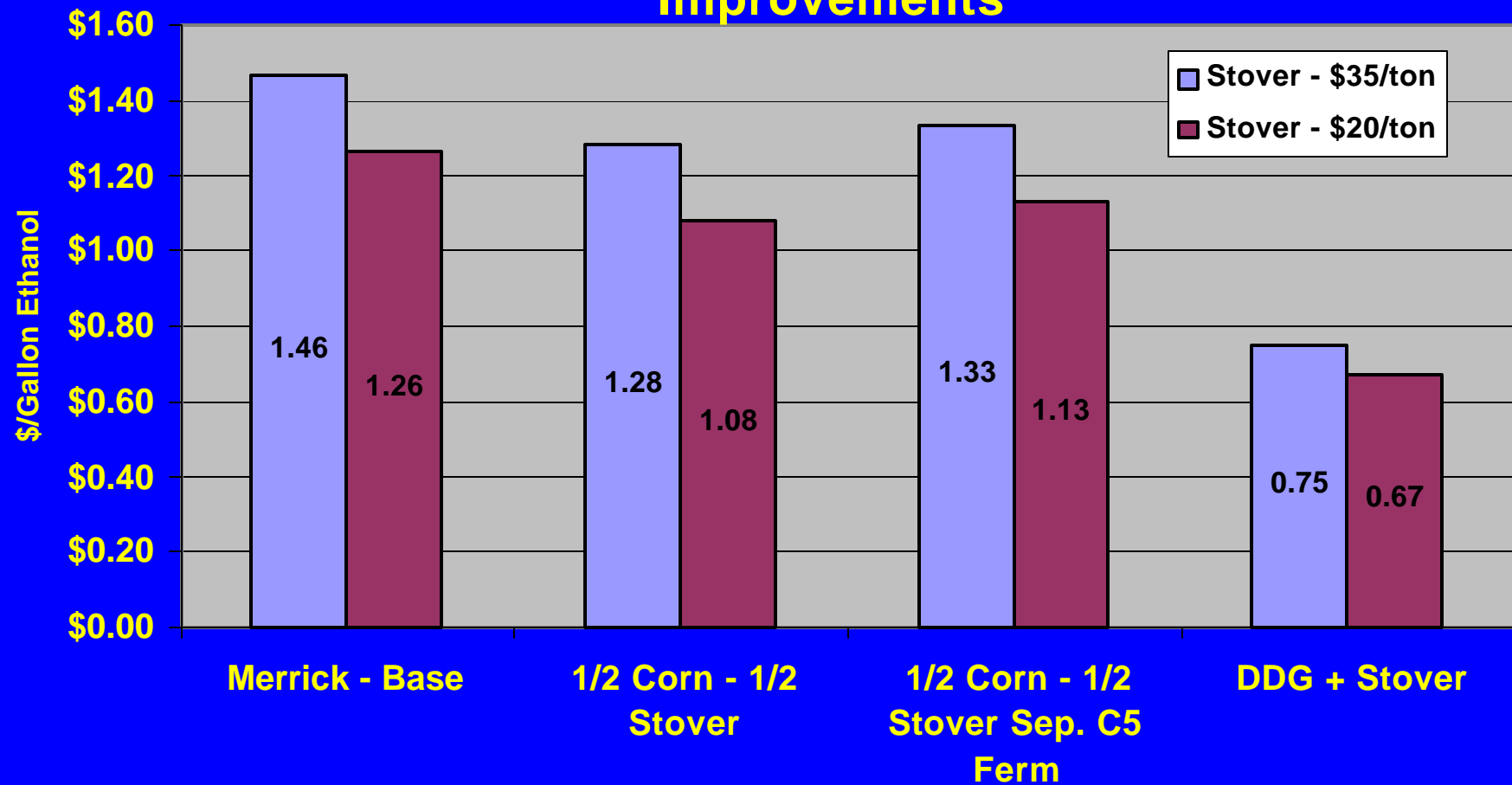
Bridge Results

“We have reduced the costs of corn ethanol considerably since 1980 and after doing this study I am confident that we can do the same for this technology.”

Gunter Brodl, Vogelbusch, USA



Ethanol Selling Cost with 10% ROI Variations on Merrick Study with Enzyme Improvements





Purdue - Williams - USDA Bridge Study

The Process:

- Hot water pretreatment of corn fiber plus enzymes
- Soluble oligomers are enzymatically hydrolyzed
- Add liquor to existing fermentation
- Assume residual fiber is sold at current price



Purdue - Williams - USDA Bridge Study Results

- Potential increase of about 8% in ethanol production
- Process yields: 50% glucan, 95% hydrolysis of oligomers and 90% fermentation
 - ethanol cost, including capital, about \$0.82/gallon
- Enzyme cost of about \$0.03/gallon ethanol for soluble oligomer conversion
- Williams is planning:
 - vendor validation of critical equipment
 - an integrated pilot plant to demonstrate hot water pretreatment using a significant portion of fiber



Bridge Study Benefits

- Gave engineering firms the opportunity to study biomass collection and handling and lignocellulosic ethanol production
- NREL design and costs evaluated and generally validated by participants
- Identified players in corn stover collection



Additional Benefits

- Identified that stover is of long-term interest to corn ethanol producers
- Helped foster ongoing relationships with corn processors interested in biomass (stover) conversion:

Chief

Chippewa

High Plains

Williams



New Relationships with the Corn Ethanol Industry:

- CRA/NCGA CRADAs '97-Present
 - Fermentation organism development
- Cargill Dow CRADA
 - Corn fiber and stover conversion
- USDA/NREL joint project phase II
 - Integrated corn and stover process design
- Possible CRADA with Broin & Associates to explore dry mill improvements



For More Information

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